Bibliometric Analysis of an Improved Video Steganography Technique Resistant to H.264 Compression

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ABSTRACT

The need for secure and robust multimedia communication has driven significant advances in video steganography. This paper proposes an improved frame selection-based data hiding scheme that combines analysis of object motion, modified entropy, and the psychovisual threshold of Discrete Cosine Transformation (DCT) to achieve high visibility and robustness against H.264 compression. A published bibliometric study from 2021–2025 reveals strong research growth in motion vector domain embedding, hybrid DCT deep learning approaches, compression-aware design for H.264/HEVC, and integration of encryption with error correction for better endurance. The results of the experiment using 14 benchmark videos showed that the proposed scheme achieved higher Signal to Peak Noise Ratio (PSNR) and Cross Correlation (NC) values compared to the latest method, in line with current research trends.

Keywords: Video Steganography, Steganography, Motion Analysis, H.264 Compression, Encryption

INTRODUCTION

The rapid expansion of internet communication has strengthened the demand for secure data concealment methods. Video steganography, which hides secret messages in video content, offers advantages over image and audio steganography due to its redundancy and higher concealment capacity. However, common compression techniques such as H.264 can severely degrade hidden data, as the quantisation process destroys subtle modifications in pixels or frequency domains.

Traditional approaches, such as Least Important Bit (LSB) embedding, provide high sealability but are brittle under compression. This has prompted the exploration of transformation domain methods (e.g., DCT, DWT), perceptual models (psychovisual thresholds), and smart frame selection techniques to ensure that hidden data survives compression while maintaining visual quality.

This research proposes a frame selection scheme based on object motion and modified entropy, coupled with a DCT-based psychovisual-based embedding method. The goal is to improve visibility and robustness under H.264 compression. The proposed scheme is placed in the current research landscape through a bibliometric analysis of studies published between 2021 and 2025.

Motion Vector (Mv) Domain Ebedding

Between 2021 and 2025, there will be a significant increase in methods operating directly in the vector domain of compressed video streaming motion. Unlike the spatial domain method, MV-based embedding exploits temporal redundancy between consecutive frames and the reduced sensitivity of the Human Visual System (HVS) to minor motion-related disturbances.

The latest MV domain method selectively modifies the motion vector in the P-frame **and** B-frame, avoiding the I-frame to maintain reference quality. Adaptive implantation schemes (2023–2025) determine the magnitude of modifications based on motion activity—embedding more bits in high-motion areas where changes are harder to detect. (1)

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MV domain embedding offers good robustness against recoding and transcoding, especially in H.264/HEVC pipelines, as it aligns with the codec's natural prediction process. However, one limitation is that the MV domain's approach relies on contentlow-motion videos provide fewer embedding opportunities. These observations are directly related to our proposed method, which also leverages motion analysis but addresses low-motion sequences by integrating modified entropy for frame selection. (2)

Compression-Aware Embedding in Codec Structures

A major development in the 2021–2025 literature is embedding strategies explicitly designed for the target codec, often H.264/AVC or H.265/HEVC. This method integrates knowledge of macro block division, intra-prediction modes, and quantization parameters into the implantation process. (3)

1. Embedding after the transformation and quantization stages to avoid hidden data loss in the next compression step.
2. Target non-reference macro blocks or high-texture areas in the transformation domain to maximize visibility.
3. Use rate distortion optimization (RDO) metrics to select embedding sites that will have minimal impact on bitrate and visual quality.

Our psychovisual implantation of DCT is in line with this direction because DCT is a natural transformation in H.264. By embedding an insignificant psychovisual coefficient, we indirectly achieve a form of conscious concealment of the codec without the need for full integration into the coder. However, incorporating macro block type awareness can further enhance the resilience of our schemes, especially under aggressive recoding. (4)

Hybrid Transform–Machine Learning Models

One of the fastest-growing areas of research since 2022 has been the combination of traditional transformational domain methods (DCT, DWT) with machine learning models, particularly convolutional neural networks (CNNs)and generative adversary networks (GANs). (5) While classic transformations like DCT provide a mathematically efficient way to embed data, they operate with fixed rules. ML-based systems can predict the optimal embedding location for a particular cover video, taking into account the content characteristics and behavior of the codec. A GAN-based framework can also generate invisible interference that is tailored to survive compression. (6)

Our psychic threshold provides rule-based coefficient selection, which is lightweight and computationally effective. However, ML-guided selection can dynamically adjust thresholds based on content, potentially increasing robustness in areas of low texture or low motion—scenarios where fixed thresholds may underperform. (7)

Encryption and Error-Correction Integration

From 2023 onwards, more and more studies are integrating cryptographic algorithms (e.g., AES, RSA) with forward error correction (FEC) codes such as BCH, Reed–Solomon, or LDPC. Encryption protects the payload content, while the FEC layer ensures bit recovery even after loss compression. (8)

This double-protection approach is especially important in the context of streaming and social media, where videos undergo multiple recompressions. Without error correction, even a low BER can corrupt the entire decrypted message.

Our methods already include AES-128 encryption, ensuring security. The literature suggests that adding an FEC pre-processing step before embedding can significantly increase endurance without compromising visibility—an improvement we identified for future work. (9)

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Robustness under Social-Media Transcoding and Steganalysis

A noteworthy bibliometric observation is that more recent works test robustness not only under laboratory H.264 compression but also through social media transcoding pipelines (e.g., YouTube, Facebook, TikTok), where multiple recompressions and bitrate adjustments occur. (10)

In addition, MV-conscious tegic analysis tools have become more sophisticated, using statistical analysis on motion vector fields or residual coefficients to detect anomalies. This arms race underscores the need to embed schemes into being robust and statistically inconspicuous**.**

Our proposed modified entropy and motion analysis indeed reduces the statistical footprint by selecting an embedding site with high variability in nature. This design choice is in line with counter-steganography best practices identified in the latest literature.

Bibliometric Summary and Gap Identification

The 2021–2025 literature shows:

Two dominant clusters**:** (a) MV domain embedding for robustness and (b) hybrid–ML transformation for adaptive visibility.

Supports trends**:** codec-aware embedding, encryption+FEC integration, and real-world transcoding resilience.

The scheme we propose aligns with the MV domain cluster through motion analysis and with the constancy of the transformation domain through the psychovisual embedding of DCT. It addresses the frame selection gap by combining the motion of the object with modified entropya rare coupling in the recent literature. Future improvements could involve incorporating FEC coding and ML-assisted coefficient selection to match the top-level robustness of the latest hybrid models while maintaining computational efficiency. (11)

METHODOLOGY

The proposed scheme consists of four main phases:

Frame Selection: The video is parsed into frames, and the motion of objects is detected using 8×8 block-based motion vector analysis. Modified entropy is calculated for each frame, and frames with high motion and low entropy are selected to minimise visual distortion.

Message Encryption Secret messages are encrypted using AES-128 for confidentiality.

DCT Psychovisual Embedding: Selected frames are transformed into 8×8 DCT blocks. Coefficient pairs are selected based on psychovisual thresholds to minimise the perceptual effect. The encrypted bits are embedded by modifying this coefficient according to pre-established rules.

Reconstruction: The modified frame is reassembled into a stego video, ready for delivery.

Extraction Process: The receiver uses the same frame index and motion coordinates to retrieve the relevant blocks, uses inverse DCT, recovers embedded bits, and decrypts messages.

Evaluation Metrics: Visibility is measured using Signal to Peak Noise Ratio (PSNR) and Mean Absolute Reconstruction Error (MARE). Robustness is assessed using Bit Error Rate (BER) and Normalised Cross Correlation (NC) under H.264 compression. (12, 13)

RESULT AND DISCUSSION

Invisible

Tests on 14 benchmark videos from the Derf Test Media Collection showed an average PSNR value of over 38 dB, surpassing comparable current methods from 2019–2025. This suggests that frame selection and psychovisual embedding effectively minimise visual deterioration. (14)

Robustness under H.264 Compression

Under various H.264 compression settings, the proposed scheme maintains NC values above 0.95 and BER below 0.05, demonstrating strong resistance to quantisation noise and predictive errors.

Position in Current Research

Compared to the current work (2021–2025), our scheme aligns with MV domain trends (through motion analysis) and transformation domain robustness (via DCT). Although the hybrid DCT–ML model reports slightly higher endurance in cases of extreme compression, our method offers competitive robustness without the heavy cost of deep learning calculations. Adding error correction codes, as suggested by the latest literature, can further improve performance in real-world streaming scenarios. (15)

CONCLUSION

This study presents a bibliometric analysis and experimental evaluation of a frame-selection-based video steganography scheme using modified entropy, object motion, and psychovisual embedding of DCT. A bibliometric review of the literature from 2021 to 2025 shows a clear shift towards MV domain embedding, compression-aware design, hybrid transform–ML systems, and ECC integration. Our method is in line with this trend, achieving high visibility and robustness under H.264 compression. Future work will focus on the integration of error correction coding and machine learning-based coefficient selection to further improve robustness, especially under multi-level transcodes.

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